

Giusy Falcone

Areas of Research: Autonomous Decision-Making, Autonomous Space Guidance and Control, Flight Mechanics, Hypersonic and Space Systems, Mission Design, Trajectory Optimization, Artificial Intelligence

Work

- June 2022 - **Postdoctoral Fellow**, *Robotics Institute*, Carnegie Mellon University, (Advisor: Prof. Zachary Manchester - Robotic Exploration Lab).
- Nov., 2015 – **Visiting Scholar**, *Prof. Soon-Jo Chung*, Asteroid Redirect Robotic Mission (CIF Project JPL),
Aug., 2016 University of Illinois Urbana – Champaign.

Education

- 2017 – 2022 **PhD, Aerospace Engineering, Space Systems** *University of Illinois at Urbana-Champaign (UIUC)*
Advisor: Prof. Zachary R. Putnam
Thesis: "Autonomous Guidance and Decision-making for Planetary Aerobraking"
- 2017 **MS, Aerospace Engineering**, *Università di Pisa, Italy*,
Advisor: Prof. Giovanni Mengali, Prof. Soon-Jo Chung
Thesis: "Attitude Control of the Asteroid Redirect Robotic Mission Spacecraft with a Capture Boulder"
- 2013 **BA, Aerospace Engineering**, *Università di Pisa, Italy*.

Research Experience

Carnegie Mellon University

- June 2022 – **Robust Entry Guidance with Atmospheric Adaptation** *NASA*
Present **Advisor:** Prof. Z. Manchester
- Developed improved Convex Predictor-corrector Entry Guidance algorithm, which represents a middle ground between predictor-corrector guidance method and offline trajectory optimization, with inclusion of time as decision variable to increase overall algorithm robustness.
 - Developed square-root Extended Kalman Filter for online atmospheric density estimation and directly used by the guidance algorithm.
 - Current collaboration with NASA-LaRC to include CPEG on POST2.
- June 2022 – **Kilometer-Scale Space Structure from a Single Launch** *NASA NIAC Partners*: University of Washington
Present **Advisor:** Prof. Z. Manchester
- Feasibility assessment of the deployment of a space structure formed by high-expansion-ratio mechanical metamaterial to create artificial gravity.
 - Creation of a floating N-Bar non-linear dynamics in maximal coordinates subjected to spinning, linearization of the dynamical model, and assessment of the vibrational structural modes of the overall structure.
 - Development of model predictive control method for stabilization of the overall structure and evaluation of actuation positioning problem.

2017 – 2022 **Autonomous Guidance and Decision-making for Planetary Aerobraking** (*Ph.D. Dissertation*)

Advisor: Prof. Z. R. Putnam

- **Energy Depletion Guidance for Aerobraking Atmospheric Passes using Articulated Solar Panels**
 - Introduced trajectory control concept in aerobraking atmospheric passages via drag area variation, specifically through articulated solar panels.
 - Analytically solved simplified optimal control problem to the energy minimization problem while limiting thermal loads.
 - Developed energy depletion guidance algorithm for shallow, high-altitude atmospheric flight based on the family of solar panels' angle-of-attack profiles provided by the analytical optimal control solution.
 - This approach enables lower-altitude atmospheric flight and increases energy depletion by 1600% with respect to the conventional approach.
- **Autonomous Decision-Making for Aerobraking via Parallel Randomized Deep Reinforcement Learning**
 - Introduced autonomous decision-making through deep learning for aerobraking apoapsis maneuvers planning and design.
 - Developed parallel domain-randomized deep reinforcement learning (PR-DRL) architecture for computationally intensive simulation-based applications. The approach improves learning time and generalization in an intensely uncertain environment.
 - Defined procedure to convert a general aerobraking campaign to a Markov Decision-Process framework.
 - Performed sensitivity study for out-of-distributions environments to evaluate algorithm generalization capability.
- **Hybrid Model- and Simulation-Based Approach for Autonomous Aerobraking**
 - Defined limitations of using one form of autonomous technology, energy depletion guidance or PR-DRL, on aerobraking missions.
 - Developed a hierarchical hybrid (simulation- and model-based) architecture to enable collaboration between two forms of control at two different mission levels.
 - Assessed the impact of autonomous technology enhancements on mission performance, including risks and costs.
- **Closed-Form Trajectory Solution for Shallow, High-Altitude Atmospheric Flight**
 - Developed an approximate closed-form solution to the equations of motion for shallow, high-altitude atmospheric flight.
 - Used to evaluate the optimal control solution for the energy guidance algorithm in a quick and efficient manner.
- **Open-Source Aerobraking Trajectory Simulator**
 - Developed a Python-based, 6-DOF modeling and simulation tool to assess flight performance for aerobraking missions.
 - This tool is designed to simulate an entire aerobraking campaign, an orbit, or an atmospheric passage around Earth, Mars, or Venus while providing estimates of flight performance parameters.
 - Designed to perform Monte Carlo uncertainty analysis.
 - Uploaded to GitHub for the benefit of the entire aerospace community. [🔗](#)

2021 – 2022 **One-Size-Fits-Most Space Propulsion** (*Funding: DARPA*) **Partners:** University of Southampton, Froberg Aerospace LLC

PI: Prof. J. L. Rovey, **Advisor:** Prof. Z. R. Putnam

A study to determine the capabilities of a multimode propulsion system for providing and assisting constellations of clients in geostationary and low-Earth orbits (GEO and LEO).

- Identified and quantified uncertainties and their potential impact on multimode systems' performance.
- Developed a novel Markov Chain Monte Carlo (MCMC) sampling architecture to simulate random space missions for a general space application.
- Developed correlated performance indices based on the MCMC results to compare different spacecraft designs in terms of capability, flexibility, and performance.
- Compared different propulsion system options for LEO and GEO servicer missions using the MCMC approach in order to provide guidelines for future missions.

2021 **Mars Distributed Landed Networks - Revolutionizing Access to the Mars Surface**

Organizer: Keck Institute for Space Studies, CALTECH

Working group established to assess the scientific value, technological feasibility, and challenges of performing a small lander network mission as a possible component of the next generation of Mars missions.

2017 – 2018 **Chariot to the Moons of Mars** (*Funding: NASA Science Mission Directorate*)

Partners: Purdue University, Arizona State University, Tyvak Inc., JPL Team Xc, **PI:** Prof. D. Minton
A science-driven planetary small satellite mission concept designed to investigate Phobos and Deimos and demonstrate drag-modulated aerocapture for orbit insertion purposes.

- Responsible for mission design, planning, and design of the aerocapture maneuver.
- Designed trajectory and concept-of-operations for the pre-, in-, and post-aerocapture phases using GMAT and aeroassist simulator.
- Developed a preliminary design of the spacecraft and designed the cruise/aerocapture flight system.
- Conducted sensitivity analysis and uncertainty quantification of design conditions, GNC performance, and system-level design for drag-modulation aerocapture maneuver on Mars.

2015 – 2016 **Asteroid Redirect Mission** (CIF Project JPL) (*Master Thesis*)

Advisor/PI: Prof. S.J. Chung **Supervisor:** Dr. S. Bandyopadhyay; **Partners:** Dr. F. Hadaegh, Dr. M. San Martín (NASA)

- Modeled the 30-DOF non-linear dynamics of a system consisting of an ARM spacecraft and a captured uncertain boulder.
- Developed robust linear and non-linear control methods to stabilize and detumble the complex system in a largely uncertain design space.

Teaching and Mentoring Experience

Summer 2020 – **Autonomous Systems Lab**, *Teaching Assistant*, UIUC.

Fall 2020

- Head teaching assistant.
- Implemented new lab material for the course (summer appointment).
- Instructed three lab sessions per week (10 students per lab session).
- Evaluated and provided feedback on students' lab reports and project.

Fall 2019 **UAV Navigation and Control**, *Teaching Assistant*, UIUC.

- Head teaching assistant.
- Taught three lab sessions per week (16 students per lab session).
- Closely assisted the course instructor in verifying the instructed lab material.
- Evaluated and provided feedback on students' lab reports and project.

Fall 2017 – **Space System Design I & 2**, *Teaching Assistant*, UIUC.

Spring 2018


- Head teaching assistant.
- Mentored weekly groups of six to seven students in the development of their space design project.
- Evaluated and provided feedback on students' homework and project.
- Ranked "excellent" instructor by students.

2018 – 2021 **Illinois Aerospace Institute Summer Camp 2018, 2019, 2020, and 2021**, *Instructor*, UIUC.

- Created and presented 4 2.5-hour lessons to high-school students participating in the summer camp on orbital flight mechanics and mission design.
- Assisted students in their space projects.
- Engaged students through the use of technology, including Kerbal Space Program.

2017-2022 **Mentored students:** Mitchell Fogelson (graduate student MECHE-RI CMU), Kevin Tracy (graduate student RI CMU), Daniel Engel (graduate student UIUC), Thomas Smith (graduate student CU-Boulder), Marta Cortinovis (graduate student Stanford University), Karnap Patel (senior UIUC)

Invited Talks, Poster, and Workshop

- 2022 **Falcone G.** and Putnam Z. R., "Fast, Cost-Effective, Autonomous Aerobraking For The Next Generation of Mars Orbiters", 19th International Planetary Probe Workshop - IPPW-2022 - *Presentation*
- 2022 Tracy K., **Falcone G.**, and Manchester Z. , "Robust Entry Guidance With Atmospheric Adaptation", 19th International Planetary Probe Workshop - IPPW-2022 - *Poster*
- 2022 **Falcone G.**, "Autonomous Guidance and Decision-making for Planetary Aerobraking", 2022 Rising Stars in Aerospace Symposium - *Presentation*
- 2021 **Revolutionizing Access to the Martian Surface**, Keck Institute for Space Studies Workshop, California Institute of Technology - *Workshop*
- 2020 **Falcone G.** "Online Trajectory Optimization Via Solar Panel Angle-of-Attack Control for Aerobraking", 17th International Planetary Probe Workshop IPPW-2020 Webinar Series, "*Lightning invited talk from outstanding young researchers*" - *Presentation*
- 2018 **Falcone G.**, Williams J.W., and Putnam Z.R. , "Drag-modulation aerocapture on Mars: Independent capability insertion for small satellites", 15th International Planetary Probe Workshop - IPPW-2018, Outstanding Student Poster Presentation Award - *Poster*

Honors and Achievements

- 2022 Invited to participate to **2022 Rising Stars in Aerospace Symposium**, Ann and H.J. Smead Department of Aerospace Engineering Sciences at CU-Boulder
- 2022 **Graduate Student Service Award**, Aerospace Engineering Department, University of Illinois at Urbana-Champaign, award that recognizes a student for service to the unit
- 2020 **Robert Beatty Fellowship**, Aerospace Engineering Department, University of Illinois at Urbana-Champaign, award that recognizes top incoming graduate students
- 2020 **Aerospace Engineering Alumni Advisory Board Fellowship**, Aerospace Engineering Department, University of Illinois at Urbana-Champaign, award that recognizes a graduate student who excels in research
- 2020 Invited to present my research as **outstanding young researcher** to the International Planetary Probe Workshop (Entry, Descent, and Landing community)
- 2020 Selected as one of the nine students to represent the University of Illinois in the national competition for the **Schmidt Science Fellows Program**
- 2019 **Mavis Future Faculty Fellowship** program, The Grainger College of Engineering, UIUC; program to prepare students for careers in academia
- 2018-2020 **Conference Travel Award 2018, 2019, and 2020 for Graduate Students**, UIUC
- 2018 **Outstanding Poster Presentation Award**, "Drag-modulation aerocapture on Mars: Independent capability insertion for small satellites", 2nd Place, IPPW-15
- 2018- 2022 **IPPW-15 and IPPW-19 Student Scholarship Award**, International Planetary Probe Workshop 2018
- 2018 **"List of Teachers Ranked as Excellent"**, University of Illinois at Urbana-Champaign
- 2017 **PEGASUS Award**, Recognition of a special Achievement through Working Abroad for academic Research., Università of Pisa

Service

- 2017-2022 **Peer-Reviews:** (3) AIAA Journal of Spacecraft and Rockets, (2) AIAA Journal of Aerospace Information Systems, (1) Advances in Space Research, (4) AIAA SciTech Forum and Exposition

- 2022-2023 **Women, STEM, and Perks**, monthly peer-to-peer coaching sessions organized by the “Lean-In Community”
- 2017-2022 Recruitment of **underrepresented students** for the Department of Aerospace Engineering, UIUC
- 2022 **Space System Research Presentation**, Prospective Graduate Student Virtual Visit, Aerospace Engineering Department, UIUC
- 2022 **Session Chair**, SciTech Forum 2022, Learning, Reasoning, and Data-Driven Systems V Session, San Diego, CA
- 2022 **Invited Zoom session teaching class** for entire “Istituto Mattei” high school, Fiorenzuola, Italy
- 2021 **Invited Speaker** for the Women in Aerospace Research Group Discussion Panel
- 2018-2020 **Skype a Scientist**, Skype session teaching class with 3rd grade science class of the Barstow School in Kansas City, MO, and 7th grade science class of the Gies Campus of Chicago Jesuit Academy, IL
- 2011-2015 **Editor-in-Chief and Coordinator** of the International EUROAVIA Press working group, international association for aerospace engineering students
- 2011-2015 Rotation between the role of **Secretary (2011/2013), Treasurer (2013/2014) and President (2014/2015) of EUROAVIA Pisa** association, local association of EUROAVIA

Press Appearance

- 2022 NASA Langley Alumni Association Newsletter, September 2022
- 2022 2022 Annual UPDate magazine, UIUC magazine, August 2022
- 2022 Quotidiano l'Attacco (daily newspaper), February 9, 2022
- 2022 Italian National Institute of Astrophysics newsletter, January 2022

Journal Publications

- 2022 **1) Falcone G.**, and Putnam Z.R., “Autonomous Decision-Making On-Board for Aerobraking via Parallel Randomized Deep Reinforcement Learning”, *IEEE Transactions on Aerospace and Electronic Systems*, [🔗](#).
- 2021 **2) Falcone G.**, and Putnam Z.R., “Energy Depletion Guidance for Aerobraking Atmospheric Passes”, *AIAA Journal of Guidance, Control, and Dynamics*, [🔗](#).
- 2018 **3) Falcone G.**, Williams J.W., and Putnam Z.R., “Assessment of Aerocapture for Orbit Insertion of Small Satellite at Mars”, *AIAA Journal of Spacecraft and Rockets* doi:10.2514/1.A34444 [🔗](#).
- 2022 **4) Falcone G.**, Engel D., Cortinovis M., Ryan C., Rovey J., Lembeck M., and Putnam Z.R., (submitted August 2022) “Comparison of Propulsion System Options for Satellite Servicer Applications”, *AIAA Journal of Spacecraft and Rockets*.
- 2022 **5) Falcone G.**, Ryan C., Rovey J., Lembeck M. and Putnam Z.R., (submitted Sept. 2022) “Assessment of Mission Performance of Propulsion Options for Robotic Servicers using Markov-Chain Monte Carlo Architecture”, *AIAA Journal of Spacecraft and Rockets*.
- 2022 **6) Falcone G.** and Putnam Z.R., “A Hybrid Simulation- and Model-Based Architecture to Autonomous Aerobraking”, *will submit in December 2023*.

Proceedings

- 2023 **1) Tracy K., Falcone G.**, and Manchester Z., “Robust Entry Guidance with Atmospheric Adaptation”, *2023 AIAA SciTech Forum*, National Harbor, MD.

- 2022 **2) Falcone G.**, Engel D., Cortinovis M., Ryan C., Rovey J., Lembeck M. and Putnam Z.R., "Mission Performance Assessment of Multi-mode Propulsion for Satellite Servicing Applications", *IEEE Aerospace Conference*, Big Sky, MT.
- 2022 **3) Falcone G.**, and Putnam Z.R., "Deep Reinforcement Learning for Autonomous Aerobraking Maneuver Planning", *2022 AIAA SciTech Forum*, San Diego, CA. **2022 AIAA Intelligent Systems Best Paper**, [↗](#).
- 2021 **4) Keck Institute for Space Studies (KISS)**, "Revolutionizing Access to the Mars Surface." Culbert, C.J., Ehlmann, B.L., Fraeman, A.A., editors., *Final Workshop Report for the W.M. Keck Institute for Space Studies*, Pasadena, CA., [↗](#).
- 2021 **5) Falcone G.**, and Putnam Z.R., "Design and Development of an Aerobraking Trajectory Simulation Tool", *2021 AIAA SciTech Forum*, Nashville, TN.
- 2020 **6) Falcone G.**, and Putnam Z.R., "Closed-Form Trajectory Solution For Shallow, High-Altitude Atmospheric Flight", *2020 AAS/AIAA Astrodynamics Specialist Conference (AAS 20-448)*, South Lake Tahoe, CA.
- 2019 **7) Falcone G.**, and Putnam Z.R., "Aerobraking Trajectory Control Using Articulated Solar Panels", *2019 AAS/AIAA Astrodynamics Specialist Conference (AAS 19-682)*, Portland, ME, [↗](#).
- 2018 **8) Falcone G.**, Williams J.W., and Putnam Z.R., "Aerocapture System Options for Delivery of Small Satellites to Mars", *2018 AAS Guidance and Control Conference (AAS 18-052)*, Breckenridge, CO, [↗](#).
- 2016 **9) Falcone G.**, Saxena A., Bandyopadhyay S., Chung S.J. and Hadaegh F., "Attitude Control of the Asteroid Redirect Robotic Mission Spacecraft with a Captured Boulder", *AIAA SPACE Forum*, Long Beach, CA, doi:10.2514/6.2016-5645 [↗](#).

References

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